The Lawn Dart

by Michael Jansen

The Voodoo Crew

It wasn't too long after I agreed to be the Thermal Integration Manager for the Space Shuttle Advanced Solid Rocket Motor (ASRM) program that I gained an appreciation for why the thermal community was always viewed by the Shuttle Program Office as a group of "out-there" voodoo practitioners.

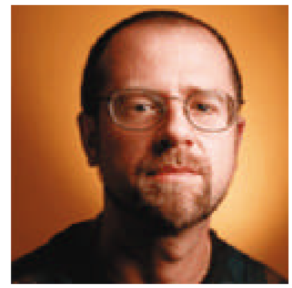
Because it was, well, *true*.

Despite a technical background that included aerothermodynamics, I was still surprised by the degree (no pun intended) to which cutting edge predictions of Shuttle ascent aerodynamic and plume heating depended on educated guesses and extremely murky empirical formulae. My new team, comprised of highly seasoned experts from two NASA Centers and a half-dozen contractor companies, apparently based its products on equations laden with fudge-factors, the values of which were argued strenuously at each meeting of the governing Thermal Panel--which I now chaired. To each prediction,a margin of safety was attached, the magnitude of which also depended on the much-argued consensus of the Thermal Panel. With this being the state of the art, no wonder our craft was viewed by outsiders as black magic.

One of the major components of ascent heating, the radiation produced by the Shuttle's two solid rocket booster plumes, was known to depend on the size and distribution of individual aluminum-bearing particles throughout each plume. Estimates of this crucial variable were crude at best, and were based on extrapolations of data collected from firings of much smaller motors with different propellant mixtures than that of the ASRM. As a result of this uncertainty, the factor of safety applied to radiation predictions was typically on the order of 100%. Such large uncertainty margins presented a significant impact to the design of the Shuttle launch vehicle's thermal protection system, as well as to the vehicle's ascent profile. The effect on the Shuttle system's payload-to-orbit capacity was not good.

But how to improve the accuracy of the prediction? Conventional means of collecting particles would have required a significant test equipment design effort; even if we could piggyback on already-planned tests, we'd have to design and build instrumented test stands able to withstand the harsh plume environments. And we had no budget for such an endeavor.

Fortunately we had our share of out-of-the-box thinkers on our voodoo team,and the thought *du jour* was... Lawn Dart!



ABOUT THE AUTHOR

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QM-6 test firing at Wasatch Operations, Morton Thiokol, Utah.

"Once the lawn dart team learned to shoot straight, we were set for a test with a real plume as target."

Seeds of Our Magic

One of the analysts had spent his early career with the Coast Guard, and was familiar with the harpoon-like guns used to hurl hawsers from Coast Guard ships to other boats to allow the two vessels to be lashed together for boarding. He assumed, and was correct,that such surplus equipment could be acquired via inter-agency requisition. His boss, a member of our Thermal Panel, proposed to me that he get a couple of these guns and have one of his co-operative education students design a particle-catching projectile for them to hurl through the plume. The scheme quickly drew the moniker "lawn dart."

Several upcoming subscale solid rocket motor tests would provide excellent opportunity to test and fine-tune the system and collect preliminary data. The major payoff would come later, if we could collect particles from the plumes of two full-scale test firings. The guns were free, the co-op needed a meaningful project to work on, and this organization's discretionary budget could handle the minor materials costs associated with fabricating whatever lawn dart design the co-op came up with.

Vital data at no cost to the program? How could I say no?

The co-op proved to be especially inventive, and devised a blunted aluminum dart, the bulbous head of which was covered with double-sided tape. The time to transit the plume was calculated short enough not to allow the contraption to melt. We secured the use of an electron microscope to allow an admittedly arduous counting of particles of

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various sizes per unit area of tape. The machine shop quickly produced several specimens, and the initial non-plume test firings initiated by remote control were successful.

Once the lawn dart team learned to shoot straight, we were set for a test with a real plume as target.

The first subscale motor test firing of the lawn dart was nearly its last. The motor sat in its vertical test stand with the exhaust end pointed skyward. Once the motor was fired and its plume was well established,the lawn dart team did its thing, whereupon the dart was promptly carried several hundreds of feet into the air with the plume, only to fall back to strike the test stand. Suddenly, the test director wasn't so sure he wanted to let our bunch near his equipment. After much cajoling, and once we reduced the dart's fin surface area, he gave us the OK for a second attempt. This one sent the dart through the plume, but not without another surprise: an unanticipated, plume-assisted journey several hundred yards out the other side–which required a determined search to find the darn thing. Nonetheless, the team was jubilant. The darts were surviving their journeys with only minor scorching, and the materials lab analysis showed we were indeed capturing excellent particle samples! After a second refinement of the dart's design, the lawn dart crew was ready for the full-scale motor tests.

As it turned out, the crew did an expert job; the darts launched during the two critical tests flew beautifully, intersected the plumes at the points of interest, and collected particle samples that allowed the analysis team to develop a repeatable particle size distribution model. Along with the concurrent radiometer measurements our team took, and the factoring in of some computational fluid dynamics predictions of the plume flow's structure, the particle data allowed us to refine our radiation models to the point that the prediction uncertainty level could be reduced from 100% to 10-15%. This represented a major leap forward in the state of the art, all made possible by some out-of-the-box thinking.

Gotta love that voodoo engineering!

Lessons

• In a problem-solving situation, all ideas (no matter how "out-there") should be considered.

• We shouldn't be so focused within our professional specialties that we forget we are the sum total of our life-experiences; the solution to a work-related problem may well lie within the memory of some totally non-work-related experience.

Question

How often do project managers use "alternative" resources to solve technical problems?

This is Michael C. Jansen's third story to appear in ASK. Like Mike's writing? Read his other two stories, Natural Relationship and Garage-Style Engineering, in previous issues.